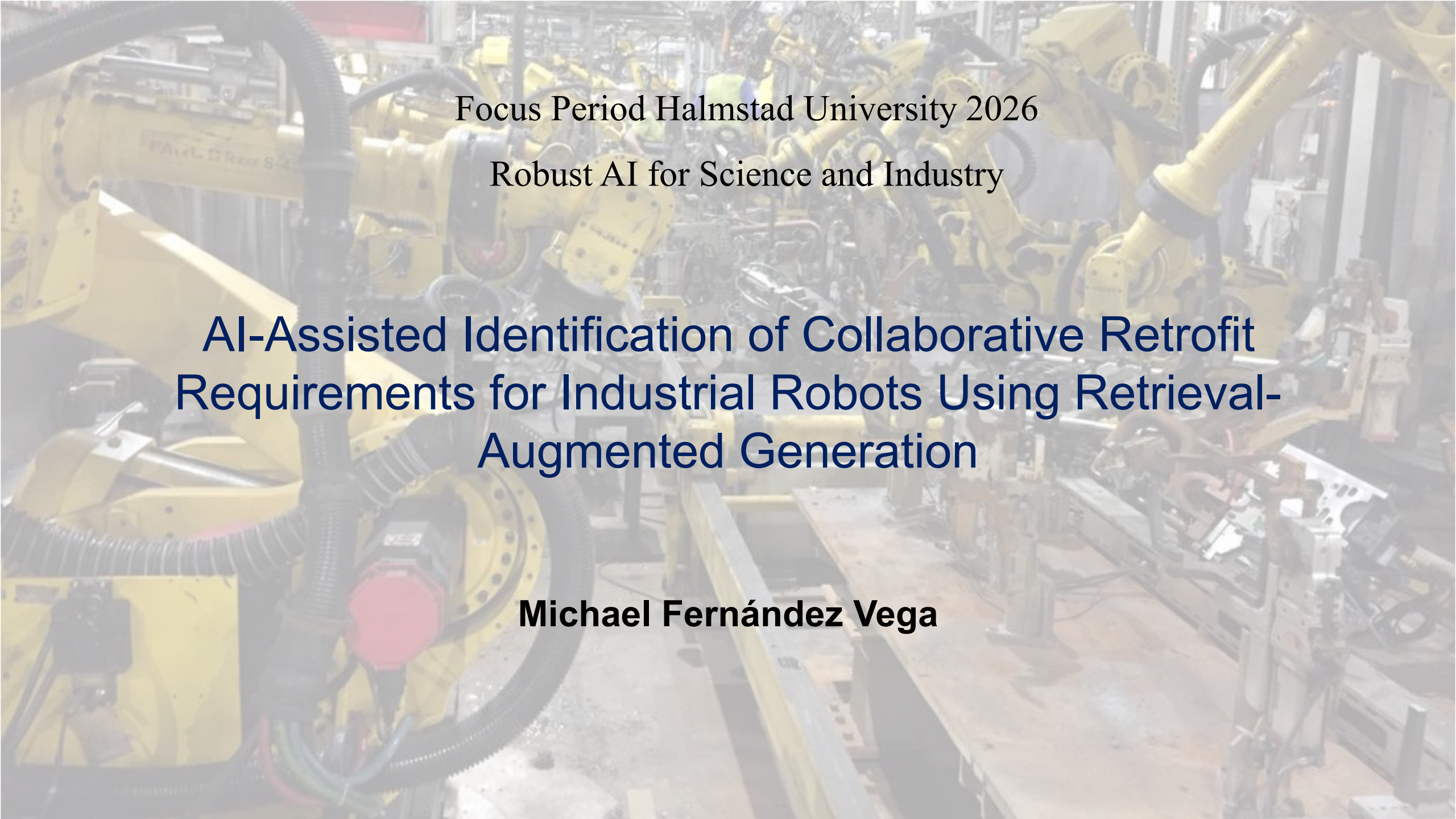


A background image showing a factory floor with several yellow industrial robotic arms. One arm in the foreground has a red emergency stop button. The scene is slightly blurred, emphasizing the text overlay.

Focus Period Halmstad University 2026

Robust AI for Science and Industry

AI-Assisted Identification of Collaborative Retrofit Requirements for Industrial Robots Using Retrieval-Augmented Generation

Michael Fernández Vega

Background

Academic Background

- University of Costa Rica
- Bachelor's Degree in Industrial Engineering
- University of Alicante
- M.Sc. in Automation and Robotics
- University of Alicante
- PhD Student in Computer Science

Professional background

- Food processing and manufacturing industry
- medical device manufacturing
- microelectronics manufacturing
- Universidad de Costa Rica

Doctoral Research Project

Transforming Robots into
Cobots: A Sustainable
Approach for Industrial
Automation

Industry 5.0 Alignment:
Sustainability, circular
economy, safe human-
robot collaboration.

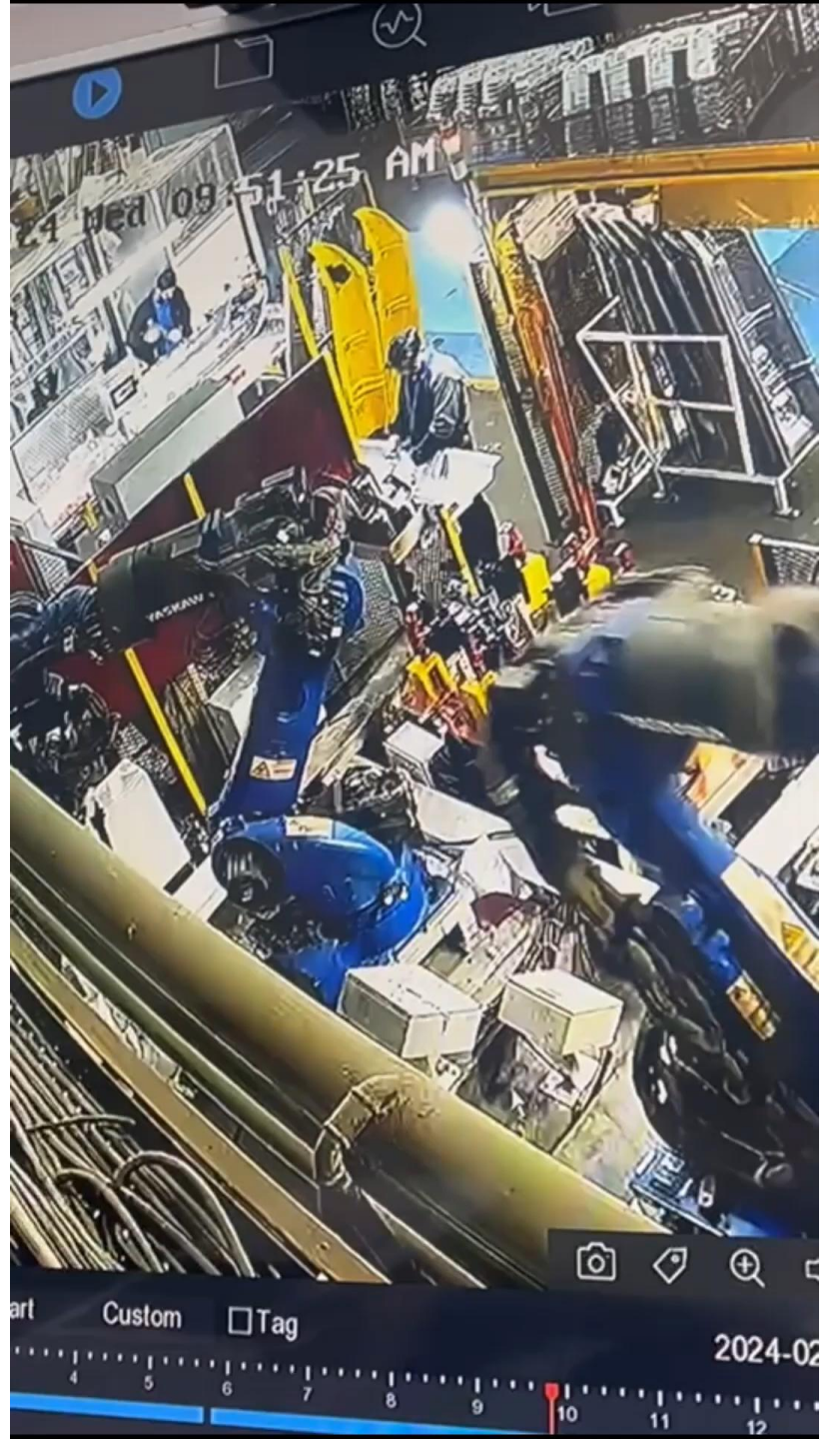
Funding: University of
Costa Rica Scholarship +
Fundación Carolina.



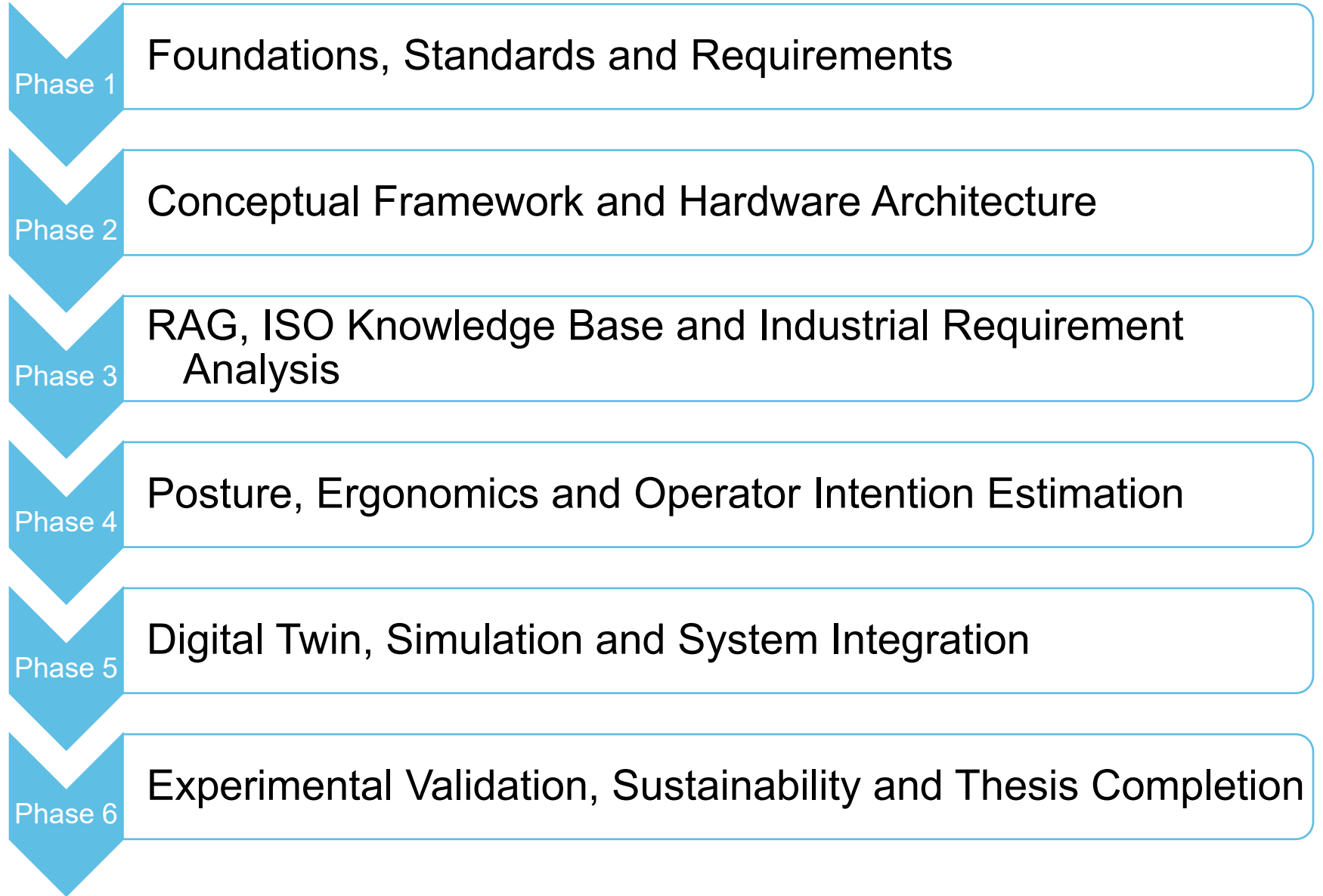
Why?



Why?



Doctoral Research Project



Papers

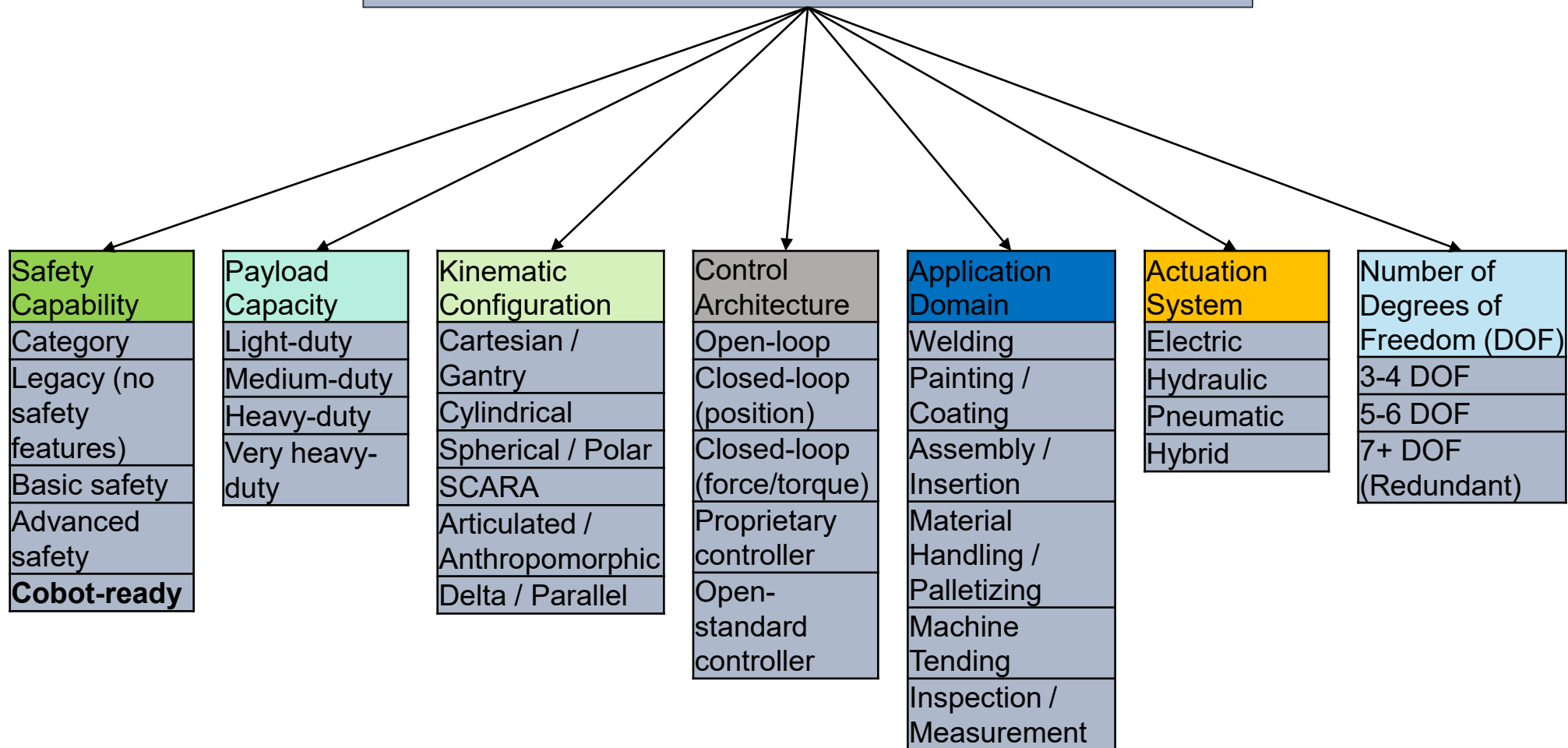
- Transforming Robots into Cobots: A Sustainable Approach to Industrial Automation.
- Towards a Comprehensive Taxonomy of Cobots: A Tool for Multi-Criteria Classification.
- A Digital Twin Framework for Multimodal Operator-Centered Human–Cobot Collaboration in Assembly Tasks.
- A Comprehensive Review of AI-Based Digital Twin Applications in Manufacturing: Integration Across Operator, Product, and Process Dimensions.
- Integrating virtual reality into welding training: An industry 5.0 approach.
- Enhancing robotics education through XR simulation: insights from the X-RAPT training framework.
- X-RAPT: A Virtual Reality Platform for Adaptive Training in Robotic Programming.
- A Multimodal Signal Fusion Framework for Continuous Fatigue Estimation in HumanCentric Environments.

How can emerging AI technologies facilitate the generation of requirements for converting industrial robots into a cobot?



Industrial Robots

General Classification of Industrial Robots



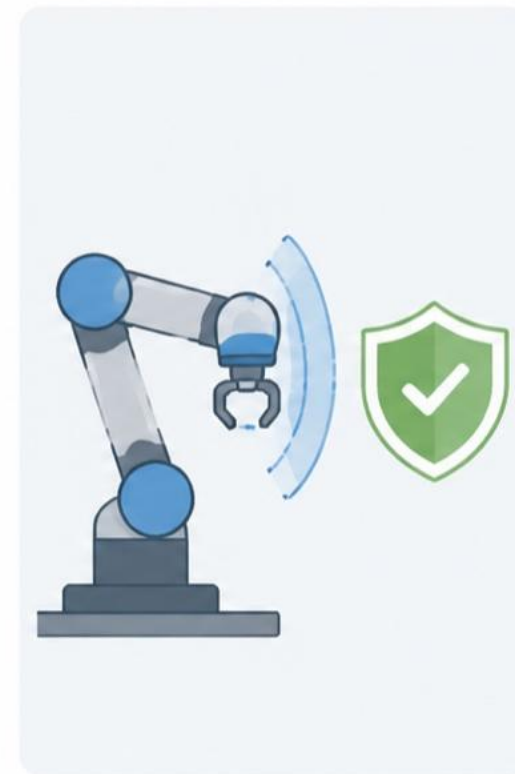
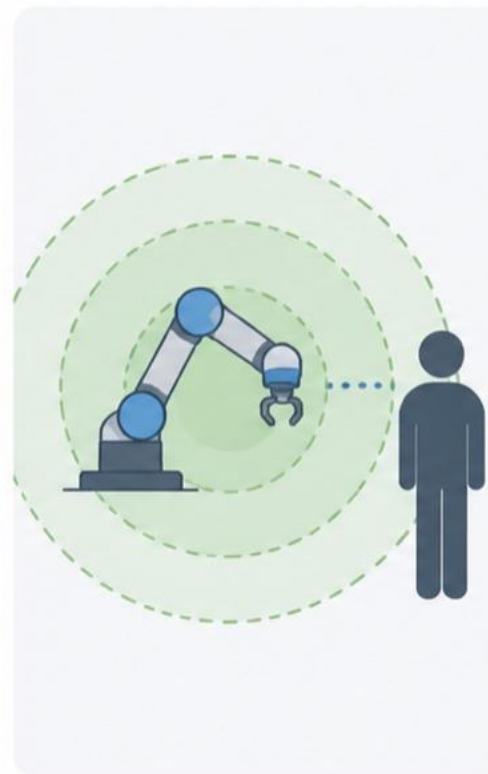
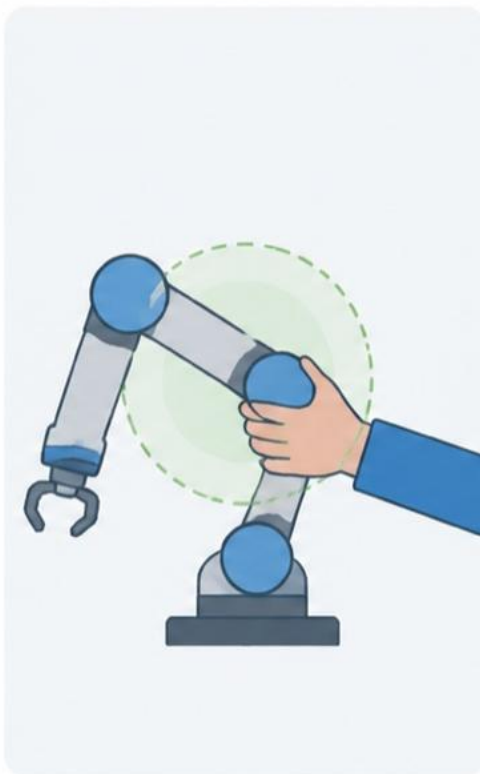
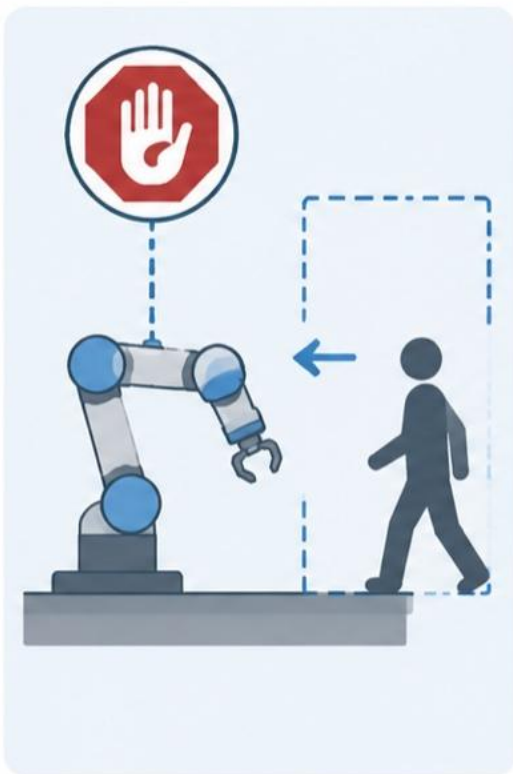
Cobots



Collaborative Robot: A robot designed for direct interaction with a human within a defined collaborative workspace

Main Standards for robotics

- **ISO/TS 15066:2016 — Robots and robotic devices — Collaborative robots**
 - Technical specification for collaborative robot systems and collaborative operation. It is commonly associated with the definition of biomechanical limits for human–robot contact, including force and pressure limits.
- **ISO 10218-1:2025 — Robotics — Safety requirements — Part 1: Industrial robots**
 - Requirements related to the robot itself.
- **ISO 10218-2:2025 — Robotics — Safety requirements — Part 2: Industrial robot applications and robot cells**
 - Requirements related to robot systems, applications, integration, and robot cells.
- **ISO 12100:2010 — Safety of machinery — General principles for design — Risk assessment and risk reduction**
 - Establishes general principles for machinery safety, including risk assessment and risk reduction.
- **ISO 13849-1:2023 — Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design**
 - Specifies principles for designing safety-related parts of control systems and defines the required **Performance Level (PL)** for safety functions.



Safety Method	How It Keeps People Safe	Typical Use
Safety-rated monitored stop	Robot stops if person enters the workspace and resumes when area is clear.	Occasional shared workspace, mostly automated operation
Hand guiding	The operator manually moves the robot under safe control.	Teaching, guided assembly, lifting assistance
Speed and separation monitoring	The robot reduces its speed or stops as a person approaches.	Frequent shared workspace with sensors
Power and force limiting (PFL)	The robot limits force so that contact remains below injury thresholds.	True side-by-side work without fences

Interconnected Threads and

Thread 1 - RAG application:

- Robot identification and selection
- Requirement gap identification using RAG + open-source LLMs.
- Initial exploratory dataset: 150 industrial robots with expert evaluations.

Thread 2 - Normative Dataset + ASSAR Case:

- Dataset expansion with ISO standards (ISO 10218-1:2025, ISO 10218-2:2025, ISO/TS 15066).
- Industrial use case: Robot without safety barrier at ASSAR Innovation Lab (Sweden).

Thread 3 - Posture Project:

- Human posture detection and ergonomic measurements.
- Use case for software component verification.
- Future: Operator intention estimation considering ergonomics.

Survey and expert

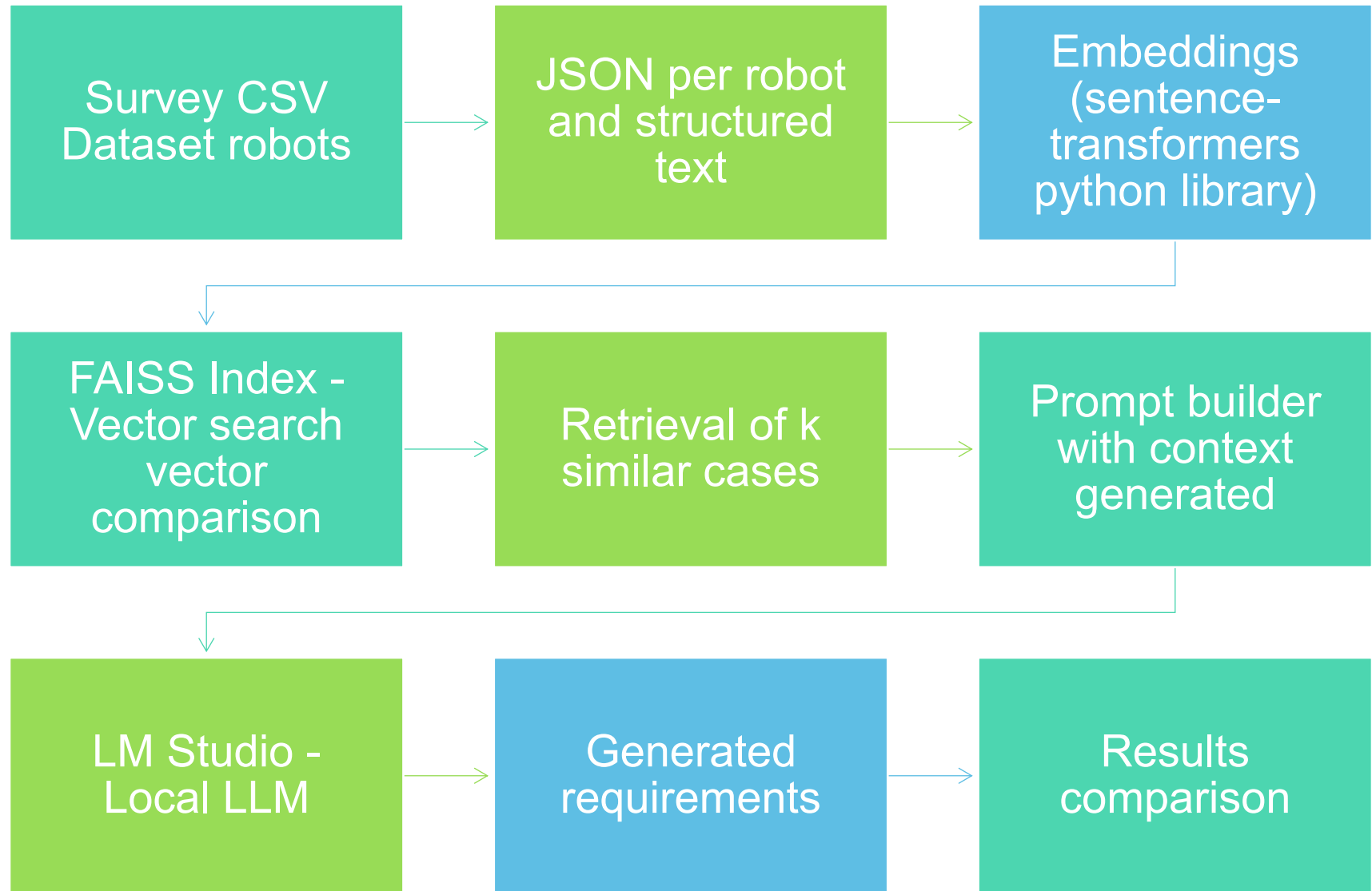
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Data collection

Level of experience in robotics 1. 3–5 years 2. 6–10 years 3. 11–15 years 4. >15 years	Primary area of specialization (multiple selection) 1. Industrial robots 2. Collaborative robots 3. Functional safety (ISO 10218 / ISO/TS 15066) 4. Control / Automation 5. Industrial integration 6. Academic research 7. Other	Previous experience with collaborative robots (cobots) 1. None 2. Basic 3. Intermediate 4. Advanced	Would you like to add any general comments about converting industrial robots into collaborative robots? (optional)	On a scale from 1 to 10, where 10 indicates the highest level of viability, how viable do you consider converting this robot into a functional and safe collaborative robot?
In your opinion, this robot is: 1. Not convertible to collaborative 2. Difficult to convert 3. Partially convertible 4. Highly convertible	Which factors primarily LIMIT its use as a collaborative robot? (Select up to 3) 1. Excessive speed 2. Lack of torque/force control 3. Lack of safety sensors 4. Rigid mechanical architecture 5. Control not designed for HRC (Human–Robot Collaboration) 6. Certification / regulatory compliance 7. Other	What elements should be added or modified to enable collaborative use? (Short answer, optional)	Even with modifications, the residual human–robot interaction risk would be: 1. Low 2. Medium 3. High	Confidence in your evaluation How confident are you in your evaluation of this robot? 1. Low 2. Medium 3. High

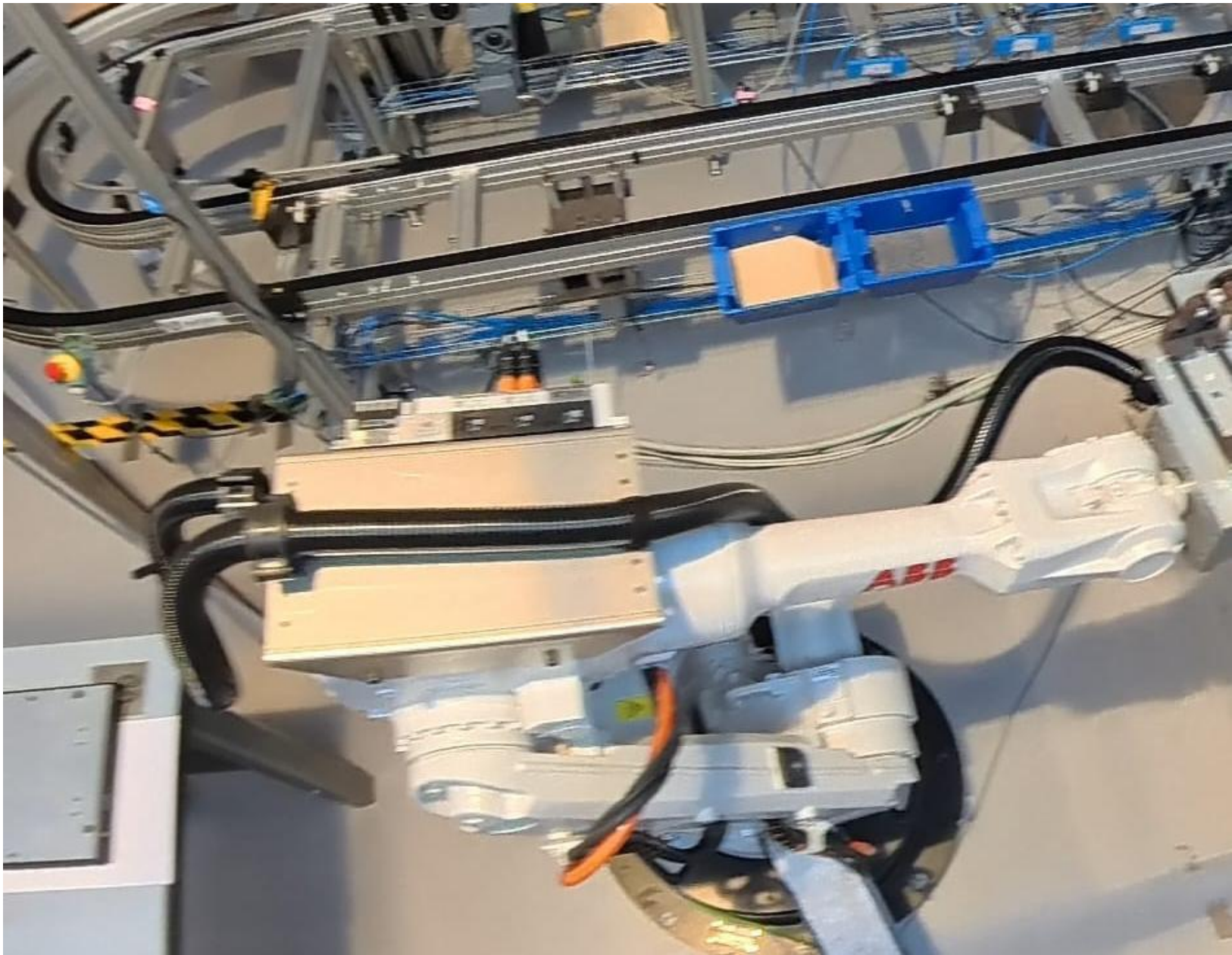
RAG Pipeline

Methodology

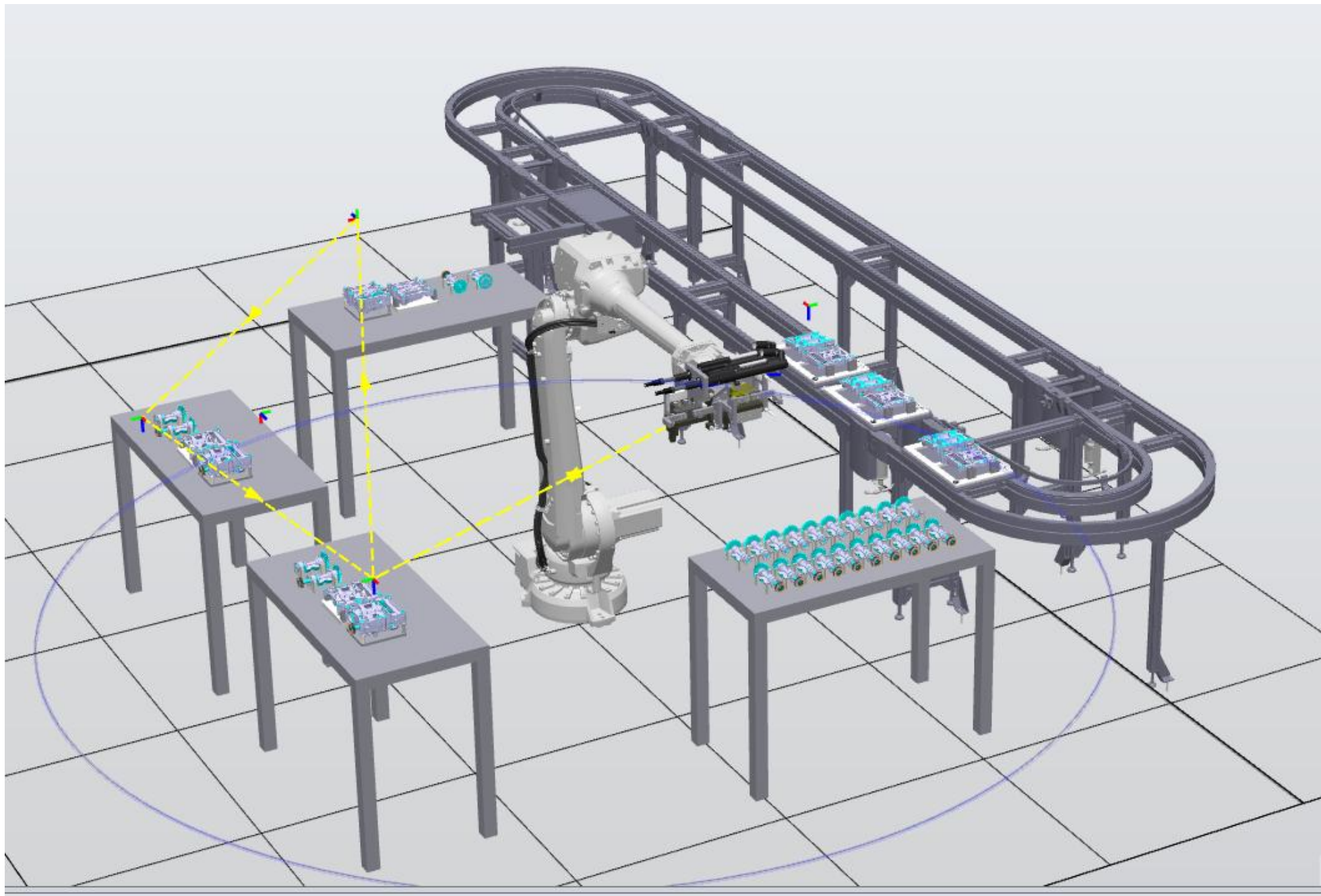


Normative Dataset

- 130 data features x 2685 robots data set
- ISO standards audit
- IRB260 standards audit
- ASSAR laboratory
- Skovde University doctoral stay
- Lab digitalization
- Use case



Simulation and systematic data generation



Data generated

manufacturer	A_manual_override_available	C_control_interface_open
model_name	A_reach_limitation_feature	C_open_sdk_available
robot_type	A_tool_interlock_present	C_teach_pendant_safety_mode
year_introduced	A_collision_surface_material	C_operator_authentication
degrees_of_freedom	A_physical_design_comments	C_realtime_monitoring
payload_capacity_kg	B_force_torque_sensor_integrated	C_diagnostics_logging
max_reach_mm	B_force_torque_sensor_optional	C_control_comments
max_joint_speed_or_rpm	B_torque_sensing_per_joint	D_human_machine_interface
max_tcp_speed_m_s	B_proximity_sensors_present	D_user_friendly_teach_pendant
robot_mass_kg	B_proximity_sensor_type	D_visual_feedback_present
power_consumption_kW	B_number_of_proximity_zones	D_audio_feedback_present
encoder_type	B_lidar_present	D_hmi_lockout_capability
control_interface_type	B_camera_present	D_collaborative_mode_switch
safetyRatedStopsAvailable	B_stereo_vision	D_remote_monitoring_support
safety_monitoring_features	B_depth_camera	D_network_protocols
onboard_sensors	B_visual_gesture_recognition	D_ros_support
force_torque_sensor_available	B_safety_light_grid_present	D_opc_ua_support
collision_detection_capability	B_safety_mats_present	D_ethernet_ip_support
compliance_or_admittance_control	B_pressure_sensors_present	D_modbus_support
external_speed_or_torque_limits	B_touch_sensors_present	D_interaction_comments
external_safety_devices_supported	B_sensor_sampling_rate_hz	E_iso10218_compliance
ip_protection_rating	B_sensor_latency_ms	E_iso_ts15066_compliance
supported_network_protocols	B_perception_comments	E_ce_marking
legacy_bus_compatibility	C_compliance_control_support	E_ul_listing
programmable_safety_functions	C_force_control_mode	E_risk_assessment_documented
redundant_mechanical_or_control_channels	C_speed_limit_mode	E_functional_safety_level
teach_pendant_available	C_power_limit_mode	E_safety_manual_available
open_source_sdk_available	C_safetyRatedMonitoring	E_maintenance_procedures_available
payload_monitoring_functions	C_safety_controller_type	E_test_reports_available
gripper_or_eoat_support	C_certified_safety_controller	E_date_of_last_certification
typical_applications	C_safetyRatedStop	E_certifying_body
general_notes	C_safe_direction_monitoring	E_certification_comments
convertible_or_modular_design	C_safe_position_monitoring	completeness_score
missing_information_flags	C_safe_speed_monitoring	data_quality_score
robot_id	C_safe_torque_monitoring	imputed_fields
manufacturer	C_control_redundancy	entry_date
model	C_firmware_update_possible	notes

Posture project Manufacturing plant



Posture, ergo and intention detection

- Posture estimates are used to infer whether the operator is in a safe/expected position relative to the UR3 robot.
- The posture node runs as part of the Vulcanexus/ROS 2 graph, subscribing to the camera image topic and publishing posture labels and confidence scores.
- This information supports human–robot interaction scenarios, such as:
- Enabling/disabling robot motion based on operator posture.
- Triggering warnings or safe-stop actions if unsafe postures are detected.
- The module is designed to be extensible: new posture classes and rules can be added without changing the core architecture.



Collaboration topics

- XAI & Interpretability: Counterfactual explanations, concept-based approaches, and evaluation metrics (sparsity, proximity) for tabular and time-series data.
- Time-Series & Streaming Data: Spatio-temporal dependencies, online continual learning, concept drift adaptation, and uncertainty quantification.
- Autonomous Systems & Robotics: Autonomous vehicles, V2X communication, drones, **cooperative perception**, and **multimodal human-robot interaction (HRI)**.
- Healthcare & Neurotechnology: Autism detection, schizophrenia cognitive analysis, BCI tools, and **medical device manufacturing**.
- Industrial AI & Industry 4.0: Anomaly detection in critical infrastructure, **additive manufacturing**, and **process optimization**.
- Advanced ML Architectures: Graph Neural Networks (GNNs), AutoML, DINOv2 attention evaluation, and link prediction.
- Hardware & Infrastructure: Antenna research, **embedded systems**, and cybersecurity.
- Applied Data Science: Handling class imbalance and bias in environmental and medical datasets.

Thanks for you attention!